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PROBABLE STRATIGRAPHICAL EQUIVALENTS OF THE COAL MEASURES OF ARKANSAS.

ONE of the most striking features connected with the coal field of the western interior basin is the enormous thickness which the productive Coal Measures appear to attain in the southern part of the area as compared with the northern and larger portion. From the Minnesota line, southward through Iowa and Missouri, to northwestern Arkansas — a distance of more than 500 miles — the principal coal-bearing series retains a thickness of not more than 500 to 600 feet. Cretaceous and Tertiary beveling and planing, as well as later erosion, have of course thinned out the beds to a feather-edge towards the east. Passing into Arkansas the formation rapidly becomes thicker until it has a vertical measurement of more than thrice that to the north. According to Branner's[1] latest estimate the "Coal Measures" of that region are over 2400 feet thick.

In the various comments upon this great thickness which the Carboniferous rocks above the Mississippian series at once assume on passing to the south side of the Boston mountains, into the Arkansas valley, no hint has been given as to the probable conditions that produced such a remarkable phenomenon.

One thing that has tended to greatly obscure the real facts has been the assumption that the old Algonkian and old Cambrian or Silurian areas of the Ozark region formed, during all Palæozoic times, a large island in the shallow continental sea. The evidence, as recently set forth, seems indisputable that not only did no "Ozark Isle" exist during late Palæozoic time, but that the present dome-shaped, island-like character of the region, with the central old rocks, and the concentric belts of newer deposits around, was not acquired until Tertiary times. Furthermore, there is every reason to believe that the Carboniferous strata once extended unbrokenly over the whole area now occupied by the uplift, and that they were removed through erosion.

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[1] Am. Jour. Sci., (4), Vol. II, p. 235, 1896.

As already remarked the great thickening of the Coal Measures begins to make itself apparent immediately south of the Boston mountains; north of this range the stratigraphy has been more or less clearly understood. The two main subdivisions are clearly defined over all of the northern region. There they represent a lower, or coastal facies and an upper, or marine phase. The plane separating them is the base of the first thick limestone above the Mississippian series. This formation is now called the Bethany limestone. It is a marked and persistent feature of surface relief from north-central Iowa, where it emerges from beneath the Cretaceous, southward through northwestern Missouri, and southeastern Kansas, to the Indian Territory line, beyond which it has not been traced in detail, although at that point it still continues to be an important and easily recognizable ridge.[1]

Regarding the southern part of the coal field much has been written, but it has only been very lately that definite data have been given, that enables comparisons with the northern districts to be made. The facts recently published have a special importance at this time for the reason that they strongly support certain views concerning the physical conditions, the existence of which have been, for some time, suspected, and enable several statements to be formulated regarding the character of Carboniferous deposition in the region. The data particularly referred to are contained in a paper by J. P. Smith[2] on the "Marine Fossils from the Coal Measures of Arkansas." While the facts therein presented are not nearly as complete as is to be desired, they nevertheless appear sufficient, when taken in connection with information derived from other sources, to permit several pregnant deductions to be made.

One of the most noticeable features of the Carboniferous deposits of Arkansas, and especially those of the western part of the state, is the prevalence of sandstones and shales above the strata of the Augusta stage (Boone chert) of the Mississippian. There are, however, in the region occupied by the Boston mountains, two limestones of unusual thickness which lie at levels considerably above the Augusta beds. These have been called[1] the Archimedes and Pentremital limestones. They are separated from each other by 40 to 75 feet of shale. The interval between the first mentioned and the limestones beneath is about 200 feet and is occupied by shales and sandstones. The Pentremital limestone may be taken, with but little doubt, as corresponding to the Kaskaskia limestone of western Illinois. Its stratigraphical, lithological and faunal characters all agree in this respect.[2] There do not appear to be any indications of a plane of unconformity at the top of this heavy Pentremital formation, as there is at the summit of an equivalent stratum along the Mississippi River. The Arkansas sequence of the Carboniferous seems unbroken and undisturbed from base to top. The Pentremital limestone may be therefore regarded as the uppermost member of the Mississippian of the region, and the overlying coal-bearing shales as the basal portion of the Coal Measures, or Des Moines series, of the more northern localities.

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[1] Am. Jour. Sci., (4), Vol. II, pp. 222–225, 1896.

[2] Proc. American Philos. Soc., Vol. XXXV, pp. 213–285, 1896.

In regard to the upper limits of the Arkansas valley Coal Measures, or of any definitely determinable horizon in the great succession, there are not yet at hand any very critical data. The lately issued notes of Smith[3] on the fossils collected in the region by the members of the Arkansas Geological Survey give the first tangible facts that have been obtained, and by which any comparison whatever can be made with the better known region north of the Boston mountains.

All who have worked in the Arkansas valley agree in assigning a very great thickness to the Coal Measures of that region. This is readily inferred from the writings of Chance,[4]

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[1] SIMONDS, Arkansas Geol. Surv., Ann. Rept. 1888, Vol. II, p. 26, 1891.

[2] American Geologist, Vol. XVI, pp. 86–91, 1895.

[3] Loc. cit.

[4] Trans. American Inst. Min. Eng., Vol. XVIII, pp. 653–661, 1890.

Winslow,[1] Stevenson,[2] Branner[3] and others. While the total thickness of the Coal Measures is doubtless somewhat overestimated by these authors, it is manifest that the formation is very thick—several times as great as it is farther northward.

The subdivisions of the Arkansas Coal Measures that have been recognized have not always been the same. In several instances they have been quite different. The classifications have been either noncommittal as to exact correlation with other regions, or they have been very general. The members distinguished have been largely for convenience in local field work. The tendency has been, however, to regard the Coal Measures of this region as about equivalent to the Coal Measures ("upper and lower divisions") of other districts north and east, with the intimation, in the later notes, that the so-called Permian of the western part of the Mississippi basin, may be present to some extent, as for example on Poteau mountain. In the latest contribution to the subject by Smith,[4] the "Upper Coal Measures" and the "Lower Coal Measures" of the Arkansas valley are paralleled with the similarly named formations of the Missouri region. The Poteau mountain beds are included. The conclusion is that "there is not sufficient reason for classing the Poteau mountain beds with the Permian, but their fauna, as well as stratigraphic position, place them very high in the Coal Measures, since they are like the fauna and position of the Mississippi valley Upper Coal Measures. These beds derive an additional interest from the fact that on Poteau mountain 1000 feet of shale, in which no fossils were sought for, lie above the thin layer from which the entire collection was taken ; thus the chance of finding true Permian beds in that region are very good." From this it will be seen at once that the Arkansas section is regarded as representing the Des Moines and Missourian series of Missouri and Kansas, as embraced between the Mississippian limestones and the Cottonwood limestone of the central part of the last mentioned state.

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[1] Bull. Geol. Soc. America, Vol. II, pp. 225-242, 1891.

[2] Trans. New York Acad. Sci., Vol. XV, pp. 50-61, 1895.

[3] Am. Jour. Sci., (4), Vol. II, p. 235, 1896.

[4] Loc. cit.

A careful comparison of the species of fossils that are considered by Smith from the "Upper Coal Measures" with those from the Upper and Lower Coal Measures of other parts of the Western Interior basin brings out the fact that the Arkansas fauna not only does not necessarily indicate a "very high" position in the Upper Coal Measures of the zone containing it, but that it may be, and probably is, very low. Judging from the fauna alone, and as a whole, according to the palæontological standard of its nearest and most closely related districts—the Missouri-Kansas province, with which it is properly compared—the indications are that the age of the strata yielding it is not that of the "Upper Coal Measures" at all, but of the "lower division"—that is, of the Des Moines series of the more northern localities.

All of the Arkansas species, with very few exceptions, are, in Iowa, Missouri and Kansas, the most widely distributed forms. Most of them range from the base to the top of the Des Moines series, and continue on upwards. In the lower series the marine beds are almost wholly absent, only a few thin limestones being present in the whole succession. Nevertheless the same species that are found in Arkansas occur abundantly not only in the thin limestone layers, which are rarely more than a few inches in thickness, but also in the calcareous shales, and, in less numbers even in the bituminous shales.

Of the corals listed from Arkansas only one form has a range that is unusually "high" in the northern succession; all of the others start almost from the very base of the series. The crinoids and bryozoans are all common in the Lower Coal Measures. All fourteen species of brachiopods are of very frequent occurence in the lower coal division, many commencing down in the Mississippian. One possible exception is *Terebratula bovidens*, which at present appears to be absent from some of the lower Des Moines beds. Of the lamellibranchs, all twenty-two species are the most characteristic forms of the very base of the Missourian ; one-half of the number are found lower down, and no less than seven are typical Des Moines forms, in fact having an *optimum habitat* not in the marine beds but in the bituminous shales. The seven species of glossophora that are enumerated are the most abundant forms of the Lower Coal Measures throughout the northern district, and they are preeminently the characteristic fossils of the black shales everywhere. Among the ten cephalopods named, no less than five are of common occurrence in the Des Moines beds, and not infrequently they are found in the black shales ; the other five, so far as known, range low in the Missourian.

If the faunal evidence, as recently presented, is to be relied upon at all, it would appear that there are no grounds for believing that there are necessarily present in the deposits of the Arkansas valley region any strata higher than the base of the Missourian series of Missouri and Kansas.

There is, however, another reason for believing that no part of the Missourian series, or its equivalent, exists in Arkansas. The general stratigraphy as far as it is now understood, gives not only no indication of the Missourian beds being represented in the region, but points almost conclusively to their absence.

The broad belt of lowland, lying below the contour of 1000 feet, and between the Ozark uplift and the elevated region of the Great Plains, extends from the Missouri river southwestwardly into Indian Territory and then eastwardly through the Arkansas valley to the savannas of the Mississippi embayment. This lowland is occupied chiefly by shales which have relatively much less resistant powers to erosion than the limestones on either side of the belt. In Missouri the subdivisions of the Coal Measures, both "Upper" and "Lower," have been clearly made out. In Kansas Haworth[1] has traced the same divisions to the Indian Territory line, so that down to the juncture of the great lowland valley and that of the Arkansas, the surface distribution of the several formations of the Carboniferous is well known. In Indian Territory the information is not yet as full as would be desirable. Still there are enough facts at hand to indicate the general features of the main subdivisions, or series. The Missourian, or more strictly marine series, composed of important limestones, does not appear to extend down the Arkansas valley into Arkansas, nor to change very much in lithological character. The Pawhuski limestone in eastern Oklahoma, regarded by Smith[1] as representing the same horizon of "Upper Coal Measures" farther east, certainly cannot be stratigraphically equivalent to any part of the Coal Measures that exist in the same latitude in Indian Territory. While it is not yet known with certainty just what its exact equivalent is, it is quite probable that it is the southern extension of what is termed the Iola limestone in the region to the north. If this is the case, the position of the limestone exposed in the quarries at Pawhuski is very near the base of the Missourian, or "Upper Coal Measures."

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[1] Univ. Geol. Surv. Kansas, Vol. I, 1896.

If, as now appears probable, the enormously thick Coal Measures of the Arkansas valley are practically the exact equivalents of only the lower division, or the Des Moines series of the region farther north, instead of representing the entire interval between the Mississippian and the so-called Permian (Oklahoman), or that part of the Carboniferous above the Cottonwood limestone in Kansas and Oklahoma, the explanation of the great increase in the thickness southward, would seem still more difficult. There have been, however, a number of new facts recently brought out regarding the diastatic changes that have taken place in the Ozark region, and some of these have a direct bearing upon the question under consideration.

It has been lately shown[2] that during the Kaskaskia, or closing epoch of early Carboniferous times in the Mississippi valley, there was a series of rapid changes in the relations of land and sea. At the beginning of the Kaskaskia the shore line had moved southward 400 to 500 miles at least from the latitude it occupied during the St. Louis, or approximately to the latitude of the present mouth of the Missouri River. This permitted erosion of the land surface north of this point; and immediately south of it the disposition of coarse sediments, covering the other marine beds of the Mississippian. Marine deposits of the later Kaskaskia, were again laid down over the coastal deposits of the same region. With a further recession of the sea some of the territory occupied by Kaskaskia rocks was also made land and was subjected to erosion. According to the recent suggestions of Marbut[1] the shore line at this time, when it had traveled farthest to the southward, coincided very nearly with the present crest of the Ozark uplift, that extends along a line drawn from Iron Mountain to the southwest corner of the state of Missouri.

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[1] Proc. Amer. Philos. Soc., Vol. XXXV, p. 230, 1896.

[2] Bull. Geol. Soc. America, Vol. III, p. 296, 1892.

It is now a well-established fact that everywhere to the north of the present Ozark crest profound erosion took place between the time when the St. Louis limestone was deposited and that when the Coal Measures were formed. Moreover, the effect of this land degradation must have left the country very much in the condition of a peneplane, for the old land surface is a rather even one, with no marked contrasts of relief. It beveled the previously slightly tilted strata, for the Coal Measures rest on the rocks of all ages from the Silurian to the top of the Lower Carboniferous. This stratigraphic hiatus, represented by the plane of unconformity at the base of the northern Coal Measures, manifestly indicates an episode in the physical history of the region, the importance of which has been heretofore little appreciated.

In the southerly retreat of the sea during the close of Lower Carboniferous time, there was, of course, a point beyond which the shore line did not advance. Beyond this point, seawardly, deposition went on uninterruptedly, the succession of beds was continuous, and the layers were conformable throughout the Carboniferous system. Such conditions appear to have prevailed in the region of southern Missouri and northern

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[1] Missouri Geol. Surv., Vol. X, p. 82, 1896.

Arkansas. South of the Ozark crest, if the inferences already drawn are to be relied upon, deposition was continuous, not only through the Lower Carboniferous period, but also during the interval when the region farther north was a land surface being rapidly eroded. As shown elsewhere,[1] the present Ozark dome had, of course, not begun to bow up. It was not a large island during the Carboniferous, as has been generally regarded. The products of land degradation were, without doubt, dumped into the adjoining seas, just as the sediments of the present continent are being carried into the ocean to form the thick fringe of coarse shore deposits.

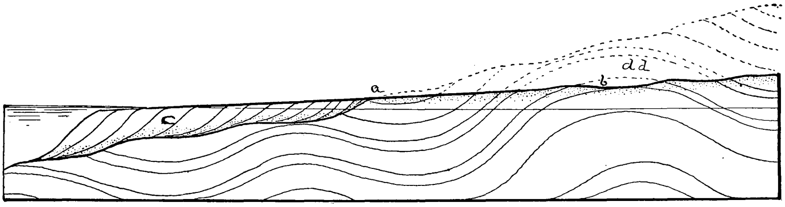

FIG. 1.—Ideal Conditions of Sedimentation.

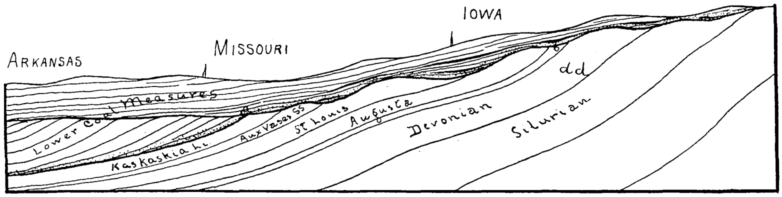

FIG. 2.—Cross Section of Mississippi Basin—Minnesota to Arkansas.

In general, the deposition of coarse sediments along the coast must have been represented by degradation on land. This phenomenon may be shown by the subjoined sketch (Fig. 1), in which *a* is the original shore line; *b*, the land surface; *c*, the sediments removed and transported from the eroded parts of the strata *d*, *d*, which had been subjected to deformation since their formation. Identically the same conditions obtained in the case of the Carboniferous deposits of the Continental Interior. It is also representative of the conditions existing at the present day on the Gulf coast, and is typical of sedimentation generally.

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[1] Missouri Geol. Surv., Vol. VIII, p. 352, 1895.

A diagrammatic cross-section, north and south, from Minnesota to central Arkansas, and representing the relations of the Carboniferous deposits of the region, is given in Fig. 2.

The true marine beds of the Missourian series, or "Upper Coal Measures," may have extended, and probably did stretch out over a considerable part, and possibly all, of the region; but erosion, since Carboniferous times, has removed all traces of these deposits.

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